EVALUATION OF REPAIRS TO CARBON-EPOXY COMPOSITES IN AIRCRAFT APPLICATIONS

Funding : Programme for Advanced Technology.

C.M. Culligan (M.ENG.) Advisor: P.J. Mallon

OBJECTIVES

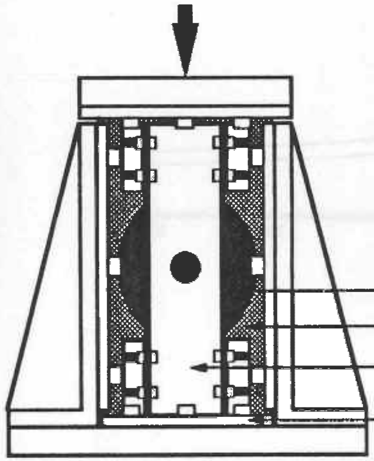
To Evaluate current Repair Techniques used for the Repair of carbon-epoxy composite aircraft components.

PROJECT APPROACH

- Manufacture of suitably sized coupons to conduct repairs and mechanical tests.
- Simulation of damage.
- Repair of damaged coupons per structural repair manuals.
- Mechanical testing of repaired coupons (Tensile and Compression tests on flat laminates and 4 pt. bend tests on sandwich beam structures.)
- Comparison of repaired strengths with damaged and undamaged control coupons.
- Comparison of repairs from various aircraft Co. structural repair manuals.

COMPRESSION RIG

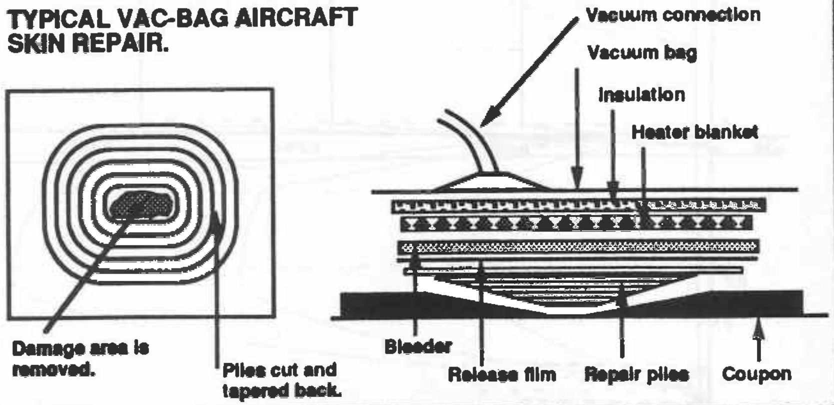
- The compression rig is designed for laminate coupons 280mm by 160mm,2mm thick i.e. 16 ply.
- To prevent buckling the coupon edges are simply supported and face supports are provided in the form of 2 channels lightly clamped at either face of the coupon.



DAMAGE SIMULATION

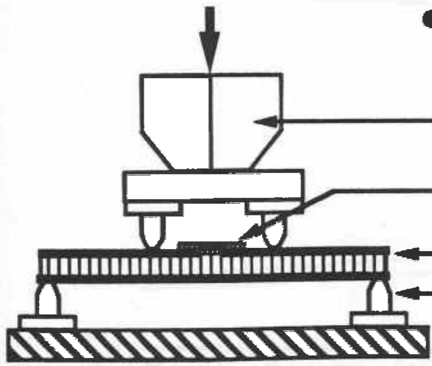
Damage is inflicted upon tensile,compression and sandwich coupons by drilling a 25mm hole representing cleaned up damage and also by using a drop weight impactor to induce delamination damage.

TYPICAL VAC-BAG AIRCRAFT SKIN REPAIR.



4 POINT BENDING RIG

- 4 Point bend test allows compression and tensile testing of thin skins i.e. 4/6 plies on a sandwich structure.
- Sandwich beam coupons are 600mm by 160mm,4/6 ply face sheets on a 38mm aluminium honeycomb core.



Plastic Media Blast (PMB) Paint Removal from Thermoplastic Composites.

John J. Lennon (M.Eng.) Advisor: P.J. Mallon
Funding: Program for Advanced Technology.

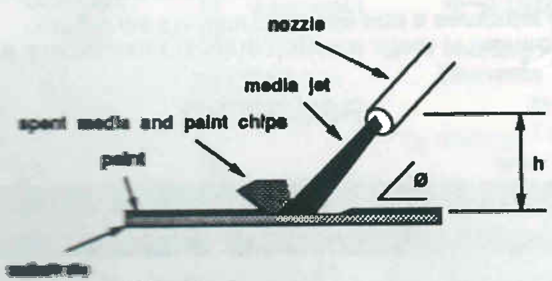
PROJECT OBJECTIVES

- To evaluate the effects of plastic media blast (PMB) on thermoplastic composites.
- To determine safe combinations of the variables in the process for use on thermoplastic composites.

APPROACH

- Manufacture of panels from thermoplastic composite materials.
- Painting of panels in accordance with British Aerospace specifications.
- Removal of paint using plastic media in a shot blasting cabinet.
- Assessment of damage caused by PMB removal process by comparing properties of stripped panels with properties of baseline (unstripped) panels.

VARIABLES IN PMB PROCESS



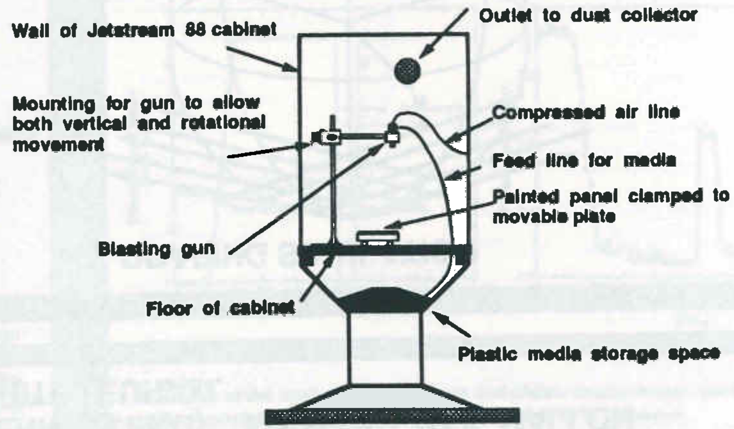
VARIABLES

(1) Blasting pressure
(2) Media hardness
(3) Media size
(4) Standoff distance h
(5) Angle of incidence Ø

BACKROUND INFORMATION

From time to time in the service life of an aircraft it must be repainted. However before the aircraft can be repainted the old paint coat must first be removed. Until the last number of years the old paint coat was removed chemically. However the chemicals used can be damaging to composite materials and also produce large quantities of toxic waste. As a result new methods for the removal process are being developed. One of these is the Plastic Media Blast (PMB) method. This approach utilises a pressurised jet of small plastic particles and is very similar to sand blasting . The figure below left shows the process and the variables involved.

DIAGRAM OF SHOT BLASTING CABINET



DESIGN OF TOOLS FOR DIAPHRAGM FORMING THERMOPLASTIC COMPOSITES

M. B. MULHERN (M.ENG) ADVISOR: PAT MALLON
FUNDING: BRITE / EURAM.

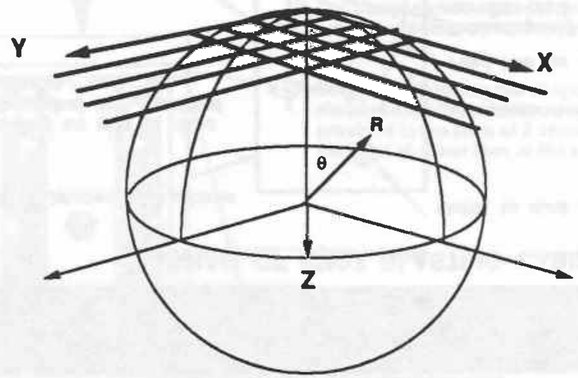
OBJECTIVE

- Analysis of the springforward effect in thermoplastic composites using finite element methods and a computer aided design program

APPROACH

- Simulate the draping process to predict fibre orientations
- Develop a finite element model of the formed part to predict the springforward effect
- Manufacture parts and compare with predictions

DRAPING SIMULATION



- Surface is generated using parametric representation
- Draping of the fibres are on to the generated surface

SPRING FORWARD EFFECT

- Spring forward effect on a ninety degree bend

- Change in angle nominally equals 1.8° (-45/0/45/90)s

FINITE ELEMENT ANALYSIS

- Thermal stresses are induced in a laminate as a result of temperature change
- The finite element analysis of a formed part yields stresses and deflections as it cools from processing temperature to room temperature

ASSUMPTIONS

1. The material layers behave macroscopically
2. Stress free temperature is 380°C
3. Material behaves orthotropically
4. No temperature gradients across laminates
5. The effect of the diaphragms on the laminate is negligible
6. The cooling rate is in the range of 10 to 700°C / min for APC 2
7. The material properties are temperature dependent

Consolidation Measurements of Thermoplastic Composite Materials

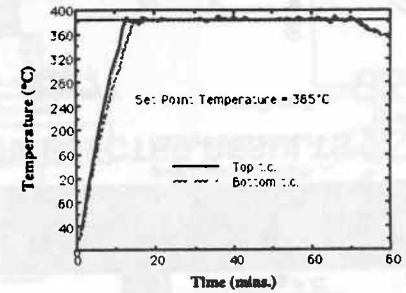
A. Mulholland (M.Eng) Advisor: P.J. Mallon
Funding: BRITE / EURAM.

OBJECTIVES

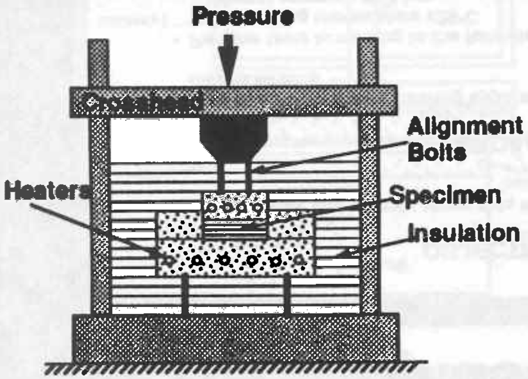
- Construct consolidation apparatus.
- Record optimum conditions for consolidating Thermoplastic Composites.
- Determine the relationship between Pressure and Transverse Flow.

APPROACH

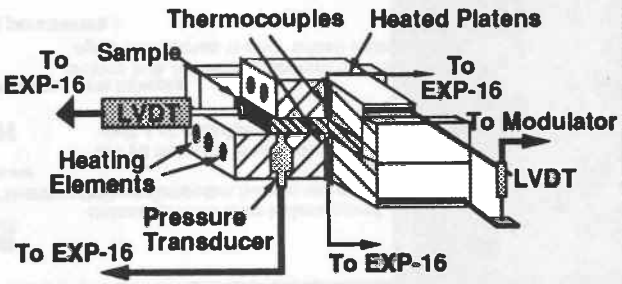
- Design and construct apparatus for consolidation experiments.
- Perform tests in pressure ranges fo 1 - 20 bar for various lay-ups.
- Full consolidation will be established by microscopic examination.
- Transverse flow will be measured as an increase in width.



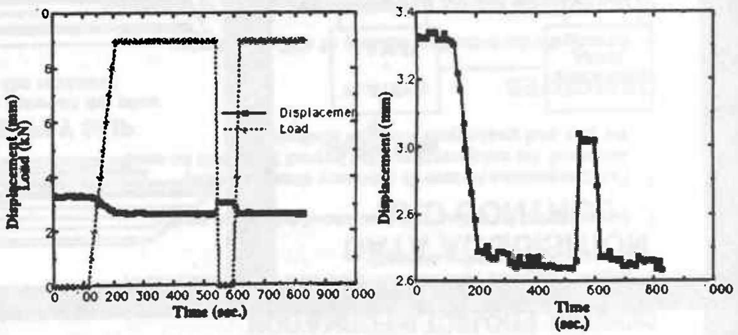
A graph of the heat-up time for the platens. The set point temperature is 385°C with the computer controlling the top and bottom platens separately. The apparatus reaches a steady state temperature after 16 minutes.



- The 'Dartec' Press can apply a load of 0 -100kN at various rates.
- Thus for a 150 x 150mm specimen, a pressure of .05 - 4.4 MPa (6.5 - 640 psi) can be achieved.



- Thermocouple readings from the top and bottom platens are processed by a PID controller and the heating elements are then turned on/off by this controller.
- Pressure and displacement readings are fed back to the computer via the EXP-16 multiplexer board and the DAS-8 analog to digital converter.
- The 'Dartec' software records the load ramps and crosshead displacement.



- Graphs of the load on the specimen and platen displacement versus time.
- The 'spring back' effect is evident when the load is removed.
- This is due to the elastic nature of the fibre bundles.

Measurement of Shear Deformation Behaviour of Thermoplastic Composites

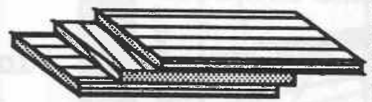
A. M. Murtagh (M. Eng.) Advisor: P.J. Mallon
Funding: BRITE/EURAM

OBJECTIVE

Obtain interply and intraply shear data for thermoplastic composites

APPROACH

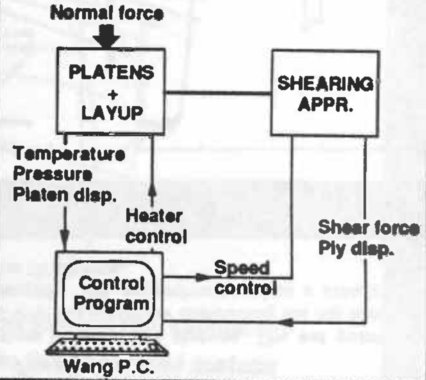
- Design and construct shearing apparatus to perform interply measurements
- Perform tests according to the following parameters :
  Processing temperature ±20°C
  Normal pressure 1 - 4 bar
  Shear rates 1 - 10 1/sec
- Evaluate effects of shear stress on layup, matrix viscosity, fibre type and material forms.
- Examine specimens microscopically to determine intraply deformations



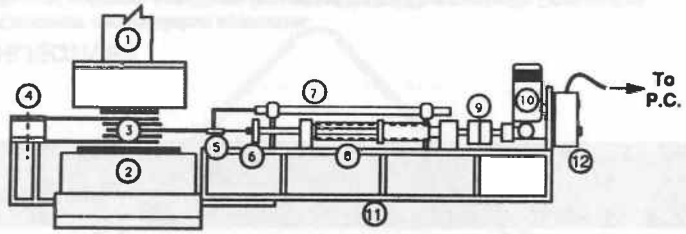
INTERPLY SLIP
(Occurs between the plies in the laminate)

INTRAPLY SLIP
(Occurs along the individual fibres in a ply)

DATA ACQUISITION AND CONTROL

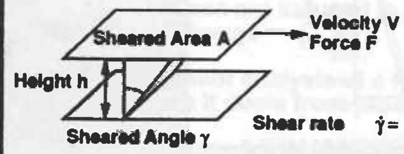


TESTING APPARATUS OUTLINE



1. DARTEC 100kN Universal Straining Frame
2. Heated platens 150 mm x 150 mm and insulation
3. Test layup
4. Rear clamping mechanism
5. Pullout ply clamp
6. 500N load cell
7. Long stroke LVDT
8. High precision leadscrew
9. Flexible coupling
10. 30 W DC motor
11. Shearing apparatus supporting frame
12. DC controller

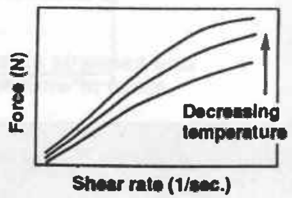
PROJECTED RESULTS

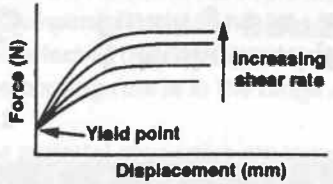


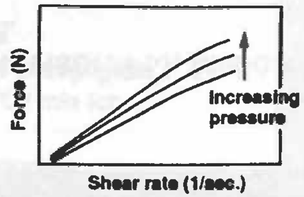
Shear rate $\dot{\gamma} = \frac{d\gamma}{dt} = \frac{v}{nh_i}$

Shear stress $\tau = \eta\dot{\gamma} = \frac{F}{A}$

η = Viscosity
n = No. of plies
h_i = Resin layer thickness







The Repair of Thermoplastic Composites Using Induction Heating

B. Rodgers (M.Eng.) Advisor: P. J. Mallon

Funding: Program for Advanced Technology

GENERAL PROJECT INFORMATION

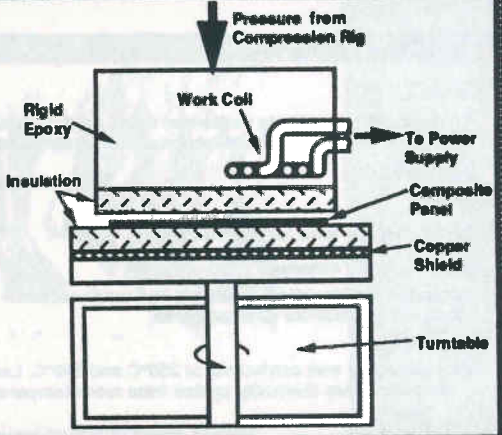
- Impact - induced delamination causes a large reduction of in-plane compressive strength
- Strength can be restored by reconsolidating the matrix
- The Composites Research Advisory Group (CRAG) standard for compression after impact tests will be used for pre- and post-repair strength analysis

OBJECTIVES

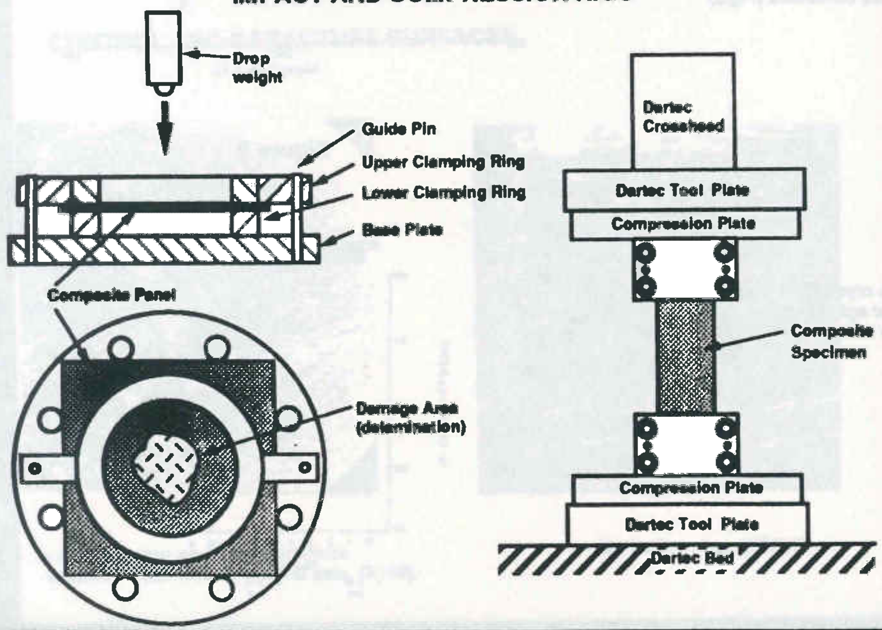
- Investigate the induction heating of APC-2 laminates
- Use induction heating with additional pressure to rejuvenate impact - damaged APC-2 laminates
- Evaluate strength recovered after repair

TURNTABLE DESIGN

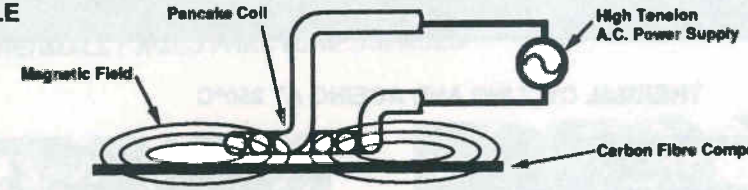
- Turntable is incorporated with a compression rig to consolidate the heated composite panel
- Temperature measurement is affected by the magnetic field - a possible solution is a fibre optic probe
- Further problems include prediction and control of the induction heater power output and edge effects



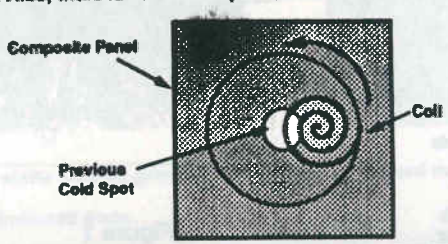
IMPACT AND COMPRESSION RIGS



INDUCTION HEATING PRINCIPLE



- The alternating magnetic field "induces" currents in the carbon fibres of the composite, causing Joule heating
- The power transmitted is a function of coil geometry, proximity to the composite, current frequency and laminate layup
- The "cold spot" is eliminated by rotating the workpiece with the coil offset. Also, there is no "skin depth" for APC-2



Crystallisation Effects In Thermally Aged APC-2 Laminates

Aidan Carew (Ph.D.)
Advisor: Dr. M. Buggy

OBJECTIVE

To determine the effects of thermal aging on the crystallisation behaviour of polyetheretherketone matrix composites

APPROACH

Material

- **APC-2, Carbon fibre reinforced PEEK.**

Manufacturing Technique

- **Compression Moulding, cross ply and unidirectional laminate geometries were prepared.**

Conditioning

- **Thermal aging was carried out at 250°C and 310°C. Laminate geometries were thermally cycled from room temperature to 250°C.**

Technique

- **%crystallinity was measured by Differential Scanning Calorimetry. Samples were cut from aged laminates at selected intervals, 0,2, 4, 8, 16, 32 and 48 weeks.**

THERMAL CYCLING AND AGEING AT 250°C

Multiple melting peaks observed

The lower melting endothermic peak appears as a movable superimposed feature on the lower side of the main peak.

It shifts to higher temperatures and becomes incorporated into the large endotherm i.e. a crystal perfection process.

Small low temperature endotherm arises due to reorganisation of crystallites and further additional crystallisation .

Laminate %crystallinity increases on stoving and cycling at 250°C for periods of up to 48 weeks (Fig. 2)

The same trends are observed for both laminate geometries whether stoved or cycled at 250°C.

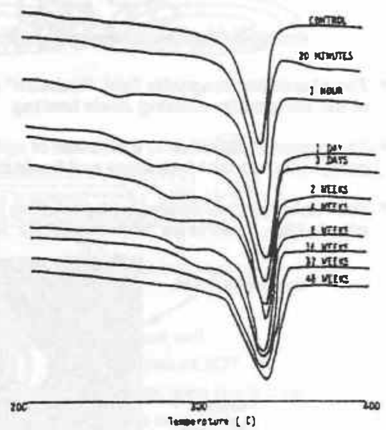


Figure 1

Typical DSC scans for aged laminates

THERMAL AGING OF LAMINATES AT 310°C

At 310°C, the crystals attain a high perfection and a single melting peak is observed.

On aging, the peak becomes sharper and narrower and moves to higher temperatures as the crystal perfection process continues (Fig.2)

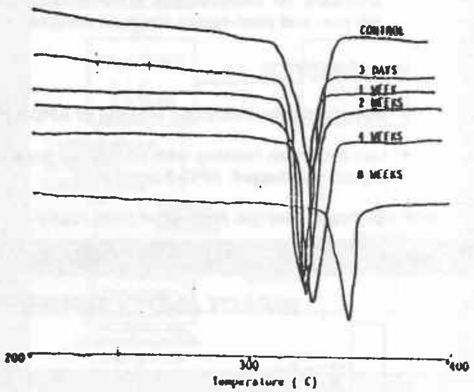


Figure 2

The % crystallinity increases initially, further aging reduces the % crystallity below that of the control . (Fig. 3)

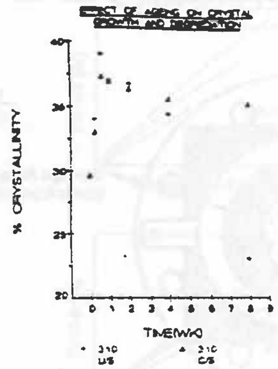


Figure 3

Fractographic Analysis of Flexural Failures in Thermally Aged APC-2 Laminates

Aidan Carew (Ph.D.)
Advisor: Dr. M. Buggy

OBJECTIVE

- To determine the effects of thermal ageing on the failure mechanisms in unidirectional APC-2 laminates.

APPROACH

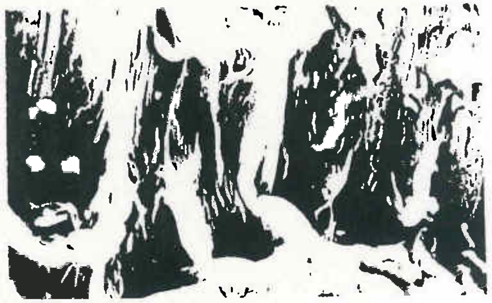
Material
- APC-2, Carbon fibre reinforced PEEK.

Manufacturing Technique
- Compression Moulding.

Conditioning
- Continuous ageing at 250°C.

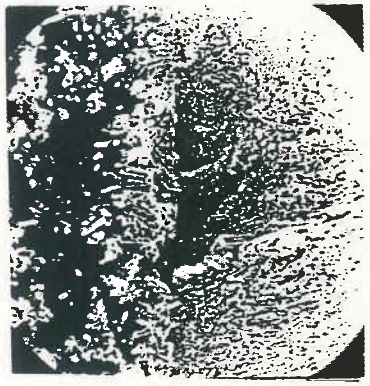
Mechanical Testing
- Room temperature flexural testing at selected intervals;0, 2, 4, 8, 16, 32, 48 wks.

Technique
- Scanning Electron Microscopy



- Matrix ductility around fractured fibres, (X2000)

CONTROL APC-2 FRACTURE SURFACES

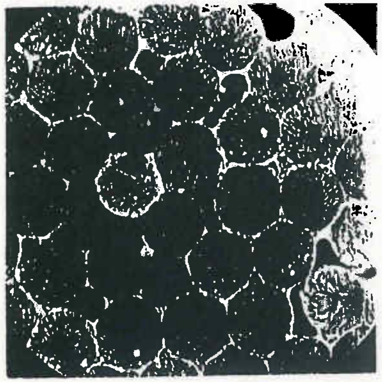


- Compressive and tensile fracture surfaces seperated by neutral axis, (X150).

- Matrix Drawing, (X2200).

THERMALLY AGED FRACTURE SUFACES

- Neutral Axis shifts towards compressive side, (X75).
- Note planar fractured areas.



- Reduced matrix ductility, fast fracture. (X2000)